

PETROLOGIC EVIDENCE FOR LOW-TEMPERATURE, POSSIBLE FLOOD-EVAPORITIC ORIGIN OF CARBONATES IN THE ALH84001 METEORITE. P. H. Warren, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA (pwarren@ucla.edu)

High-temperature models for origin of the carbonates in martian meteorite ALH84001 are implausible. The impact metasomatism (vapor-deposition) model [1], invoking reaction between fluid CO_2 and the host orthopyroxenite, implies a higher than observed proportion of residual void space. It also requires conversion of olivine into orthopyroxene, yet olivine in ALH84001 shows no depletion in carbonate-rich areas; or else conversion of orthopyroxene into silica, which should have yielded a higher silica/carbonate ratio. Likely CO_2 -vapor sources would tend to also add sulfates. Complex variants, assuming a large volume of fluid coursed through ALH84001, might alleviate the void space and silica deficit problems, but take on unattractive features of the hydrothermal model, discussed below. The impact melt model [2] implies that the fracture-linked carbonates, as products of melt injection, should appear as continuous planar veins, but in many areas they do not. The premise that rapid crystallization of impact melt determined the final distribution of the feldspathic matter is contradicted by the typically equant-granular shape of zones of feldspathic glass framed by lacy carbonates. Both vapor deposition and impact melting seem inconsistent with the zoned poikilotopic texture of many large carbonates.

The popular hydrothermal model [3] is inconsistent with the virtual absence of secondary hydrated silicates in ALH84001. Prior brecciation should have facilitated aqueous alteration. Hydrothermal fluids would be at least warm, and rate of hydration of mafic silicates obeys an Arrhenius law, at least to $\sim 100^\circ\text{C}$ [4]. Most important, hydrothermal systems, and thus hydrothermal alteration episodes, tend to last for many years.

Many areas of Mars show evidence of infrequent but extensive flooding. I propose that the carbonates formed as evaporite deposits from floodwaters that percolated through the fractures of ALH84001, but only briefly, as evaporation and groundwater flow caused the water table to quickly recede beneath the level of this rock during the later stages of the flood episode. The setting might have been a layer of megaregolith debris (perhaps dumped from the flood) beneath a surface catchment of pooled floodwater, analogous to a playa lake. In this case, carbonate precipitation would occur in response to evaporative concentration of the pooled water (Figure). To explain the scarcity of sulfates in ALH84001, the water table must be assumed to recede quickly relative to the rate of evaporation. During the period when ALH84001 was above the water table,

evaporation would have slowed, as the evaporation front passed beneath the surface of the debris layer, and possibly earlier, if the shrinking pool of surface water developed a porous sulfate crust. Alternatively, ALH84001 may have developed as a martian form of calcrete, i.e., the evaporating flood(s) may have been entirely below ground as it (they) passed slowly through ALH84001. The greatest advantage of the flood evaporite model is that it exposes ALH84001 to carbonate precipitation without exposing it to prolonged aqueous alteration. The model also seems consistent with oxygen isotopic data: $\delta^{18}\text{O}$ increasing from +5 in the early, high-Ca/Mg carbonates to +25 in later carbonates [5], an evolution opposite to that implied by closed-system fluid-carbonate fractionation.

The flood evaporite hypothesis does not seem consistent with the suggestion [6] that the ALH84001 carbonates are biogenic. Martian floods were probably too infrequent to enable evolution of flood-dependent organisms. Conceivably, however, dead organisms or their appendages were fossilized by passive engulfment in the growing carbonates.

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